FRASER RIVER
Estuary Management Program

Waste Management Activity Program
Discussion Paper

Agricultural Runoff contamination In the Fraser River Estuary

December 1990

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Prepared by

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For the

Waste Management Activity Program

Working Group

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Preface

The Waste Management Activity Program is one of seven activity programs under the Fraser River Estuary Management Program, each responsible for preparing activity plans addressing estuary wide activities. A Recommended Waste Management Activity Plan (Waste Management Activity Program Work Group, 1990), was produced earlier. Discussion papers covering in more detail some areas of concern for waste management in the Fraser River estuary have since been prepared. They include:

- Agricultural Runoff Contamination in the Fraser River Estuary
- Potential Groundwater Contamination in the Fraser River Estuary
- Potential Water Contamination From Miscellaneous Sources, Fraser River Estuary

Each discussion paper contains technical information, management strategies, and action elements required for the management of various waste sources to the estuary. Not all available information may be included, nor may all possible management alternatives be discussed. Further work may be required. The purpose of the discussion papers is to stimulate discussion regarding policy actions for control and management of wastes in the Fraser River estuary.

Copies of these reports are available from the Fraser River Estuary Management Program office.

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Introduction

Lands surrounding the Fraser River estuary are among the most agriculturally productive in Canada. In 1985, 2,897 farms containing 37,096 ha and representing a capital investment of $1,174 million produced a gross income of $268 million, or 25% of the British Columbia total (Statistics Canada, 1987). The average production value of $7,200 per hectare was more than 15 times the national average. Total expenses were $237 million.

Runoff from these agricultural lands can be a source of pollutants to the Fraser River estuary which may impart economic costs on third parties. Fisheries habitat, recreational opportunities, industrial use, and agricultural use may be impaired by contaminants in agricultural runoff.

Less is known about the nature and magnitude of agricultural pollution than for other areas of concern such as municipal effluents, industrial discharges, and urban runoff. Few programs have monitored agricultural discharges. Instead, contaminant loading figures are a product of estimated runoff flows and theoretical contaminant concentrations. Analysis of agricultural pollution is complicated by the variety of agricultural activities which include commercial or noncommercial farms, crop or animal production, and irrigated or dry-land cropping. Institutional arrangements to deal with agricultural waste management have lagged behind those for other areas.

In this discussion paper, the agricultural runoff contaminant problem is subdivided into sections that discuss the volume of agricultural runoff, contaminants in general, waste legislation, and a number of waste sources. These include chemical fertilizer applications, animal manure disposal, pesticide applications, wood waste use, composting, silage and milk parlor discharges, animal mortalities, soil erosion, and irrigation salinity. The nature and magnitude of the waste management problem is defined for each of these agricultural waste sources, along with legislation, programs, and current and recommended best management practices. Action needs, which may include research, public awareness, or development and implementation of control measures, are then summarized.

Estimates of Total Agricultural Runoff

Total runoff is estimated from land area and average rainfall, using an assumed runoff coefficient and applying a correction for irrigation or ground watering. One estimate uses the area in Agricultural Land Reserves, an average precipitation for each reach of the Fraser River estuary, an estimated amount of irrigation, and a runoff coefficient of 0.3 to derive a runoff total of 632,000 m^3/day, or 230,700,000 m^3/year, from agricultural areas within the FREMP area (table 1).

Table 1 ESTIMATED RUNOFF FROM AGRICULTURAL AREAS, 1987

Reach	Land Area in ALR (km^2)	Annual rainfall (mm)	Annual Irrigation (mm)	Runoff (m^3/day)	Runoff (million m^3/year)
Main Stem	89.0	1,650	12	121,500	44.3
North Arm	24.6	1,200	12	24,700	9.0
Main Arm	46.3	1,140	12	44,700	16.3
Fraser Tributaries	85.0	1,780	12	126,900	46.3
Little Campbell	37.3	1,270	31	40,200	14.7
Nicomekl	86.5	1,520	64	112,300	41.0
Serpentine	56.6	1,400	21	65,800	24.0
Boundary Bay	99.3	1,140	38	95,900	35.0
TOTAL	**524.6**			**632,000**	**230.7**

A coefficient of 0.3 is used to derive these runoff values. Ferguson and Hall (1979) used a coefficient of 0.2 in their estimate of agricultural runoff.

(Source: GVRD, 1988)

However, not all land within the Agricultural Land Reserve is actively farmed. Nor are all active farms within the ALR. The 1986 Census of Agriculture (Statistics Canada, 1987) indicates that actual farm area may be well below that in the Agricultural Land Reserve (table 2). Using census values for farm area, an average precipitation of 1,400 mm/year (interpolated from Wright and Trenholm, 1969), and a runoff coefficient of 0.3, annual precipitation runoff from agricultural lands would be 155,803,000 m^3/year.

Table 2 TOTAL FARM AREA IN FRASER ESTUARY CENSUS DIVISIONS, 1986

Census Division	Total Farm Area		Improved Area		Unimproved Area	
	Farms Reporting	Hectares	Farms Reporting	Hectares	Farms Reporting	Hectares
Burnaby	62	128	62	x	2	x
Delta	195	6,814	191	6,564	42	250
Langley	1,252	13,322	1,146	8,610	661	4,712
Maple Ridge	209	2,282	181	1,252	119	1,029
Pitt Meadows	177	2,708	173	2,534	55	174
Richmond	302	3,757	300	x	54	x
Surrey	700	8,085	649	6,512	333	1,573
TOTAL	**2,897**	**37,096**	**2,702**	**29,002***	**1,266**	**8,094***

x Data suppressed for confidentiality
* Suppressed data included in total
(Source: Statistics Canada, 1987)

Both surface water and groundwater withdrawals are made in the area for irrigation, ground watering, and field flooding, and some runoff occurs from these additions. Surface water withdrawal licences for irrigation and ground watering purposes total 5.3 million m^3/year (table 3), primarily in the Serpentine/Nicomekl system. A runoff coefficient needs to be applied to determine a runoff value. Presumably, good irrigation management would yield a lower coefficient than for runoff generally. Applying a coefficient of 0.2 to irrigation water would yield irrigation runoff of about 1 million m^3/year. About 6 million m^3 per year is withdrawn for flooding of cranberry fields during fall harvest periods. Most of this will be discharged to the river following the harvest. There is no estimate of groundwater withdrawal for irrigation. Total agricultural runoff, with additions, is about 162 million m^3/year.

Table 3 WATER WITHDRAWALS FOR IRRIGATION AND FIELD FLOODING IN THE FRASER RIVER ESTUARY AREA, 1990

River System	Irrigation[1]		Field Flooding	
	number of licences	volume (m^3/year)	number of licences	volume (m^3/year)
Alouette River	8	245,337	1	124,405
Campbell River	25	617,188		
Fraser River	10	601,005	8	5,613,434
Kanaka Creek	1	12,344		
Nicomekl River	54	2,471,466		
Serpentine River	32	1,353,396	1	171,582
TOTAL	**130**	**5,300,736**	**10**	**5,909,421**

[1] Includes ground watering licenses
(Source: Water Management Branch files)

Contaminants in Agricultural Runoff

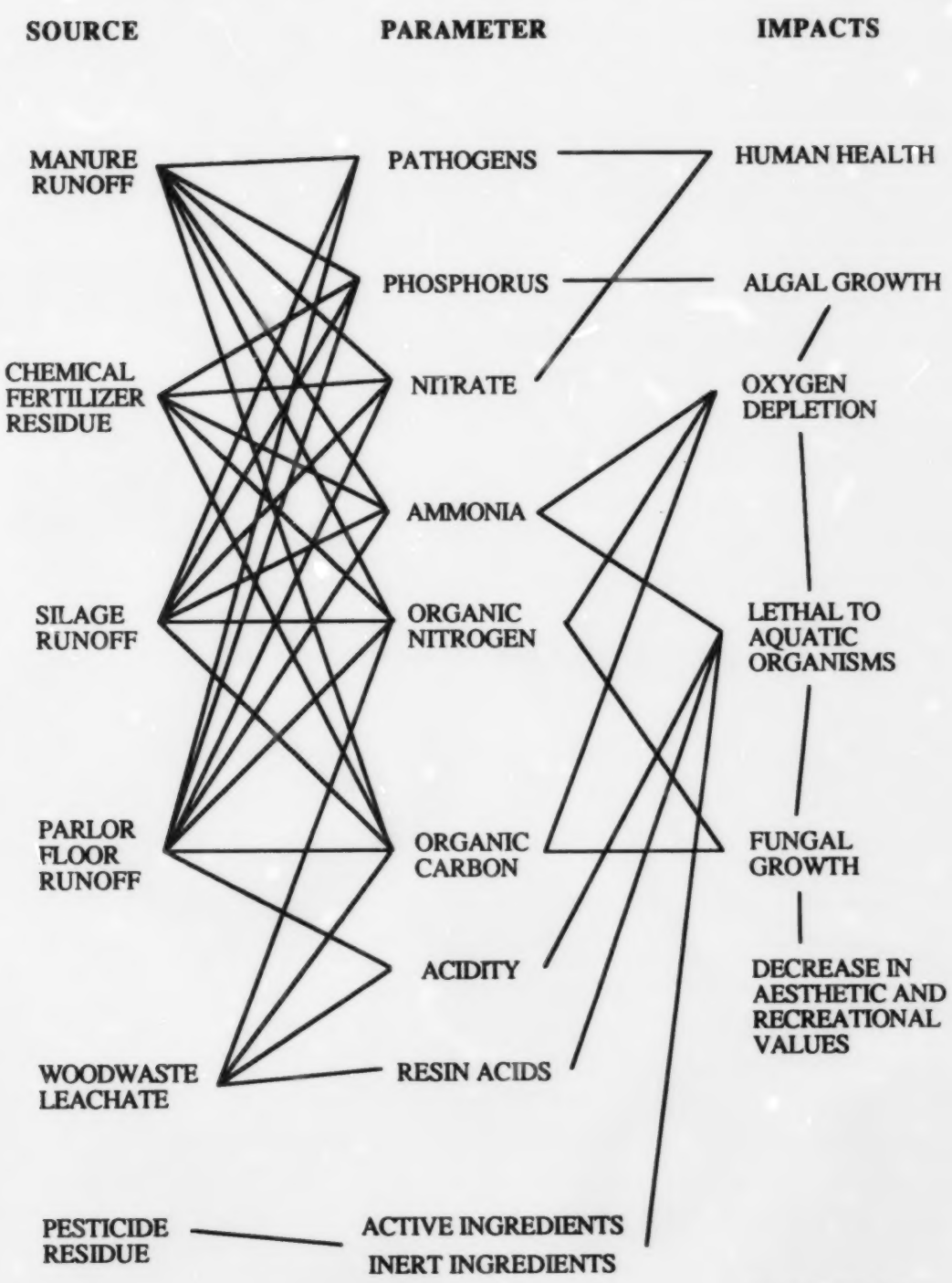
The contaminants most often identified with agricultural runoff are sediments, nutrients, salts, organic materials, pesticide residues, and pathogens (table 4). Depressed oxygen levels and toxicity are the main impacts of concern, though other impacts may also result. Major nutrients include nitrogen, phosphorus, potassium, and organic carbon. Nitrogen may be in several forms, including nitrite, nitrate, ammonia, and organic nitrogen. Ammonia may be directly toxic to fish and can be indirectly toxic by lowering oxygen levels in streams. Organic carbon and nitrogen also act to depress oxygen levels, and may also promote fungal growth. Phosphorus is a key nutrient in promoting algal growth in streams. Both algal and fungus growths impair the fisheries resource and damage recreational and aesthetic values of the water. Fall algal die-off reduces water oxygen levels as oxygen is demanded during decomposition. Nitrate may represent a health risk if present at elevated levels in drinking water. Nitrate is the cause of methemoglobinemia, and it has also been implicated in birth defects, cancer, and nervous system impairment (CAST, 1985). Other impacts from agricultural wastes include elevated acidity from parlor floor effluents or wood waste leachates, health risks from bacteriological contamination, and toxicity from pesticide residues (figure 1).

Table 4 AGRICULTURAL PRODUCTION ACTIVITIES AND RELATED POLLUTANTS

Pollutant	Crop Production		Animal Production		Major Associated Impact
	Irrig.	Non-Irrig.	Confined	Pasture	
Sediments	o	x	o	x	Turbidity
Nutrients	o	o	o	x	Eutrophication, oxygen stress
Salts	x	--	o	--	Fluctuations in salinity
Organic material	o	o	x	o	Oxygen stress
Pesticides	o	o	--	--	Toxicity
Pathogens	o	o	o	o	Human health hazard

x principal problem resulting from activity
o secondary problem
-- minor or negligible
(Source: Puget Sound Water Quality Authority, 1986)

Figure 1
ENVIRONMENTAL IMPACTS OF AGRICULTURAL WASTES



(After Moore, 1989)

The amount of agricultural pollution depends on both environmental factors and land treatment practices. Environmental factors include the amount and intensity of precipitation, runoff, and sedimentation. Cropping practices generating pollutants include soil tillage or compaction, alteration in natural cover, increasing available nutrients, applying chemicals, and irrigation. These operate by adding material that may contaminate runoff, and by increasing the amount of runoff. Animal keeping and production activities that can pollute include concentrating animals in a small area, overgrazing, and allowing animal access to streams. Again, these activities add material to runoff as well as increase the amount of runoff.

The contaminants in agricultural runoff can be highly concentrated and can severely damage the receiving waters even when significant dilution occurs (Moore, 1989). Cumulative impacts arise when more than one farm is discharging contaminated runoff to a creek system. Small or intermittent flows can accumulate in slow moving drainage ditches or tributary streams, then deliver a major slug of polluted water to streams at the onset of heavy precipitation. Thus, the receiving water concentration of contaminants from agricultural waste periodically varies from safe to unsatisfactory or toxic. Oxygen levels, for example, may be satisfactory for all but two weeks of the year, but these two weeks may coincide with major salmon runs. Low oxygen levels on 2 October 1980 and 28 October 1984 killed over half of the Serpentine River coho run before it could spawn (tables 5 and 6).

Water chemistry and effluent quality are monitored by Environmental Protection, MOE, staff and contractors. Reports may also be prepared regarding specific waste practices and their environmental consequences (table 7). Environmental Protection, Environment Canada, and Water Management, MOE, also monitor water quality conditions.

Agricultural land use within the Fraser River estuary area is concentrated in the Serpentine, Nicomekl, and Campbell River watersheds, Richmond, Delta, and the Alouette River/Pitt Polder system in Pitt Meadows. Most knowledge of agricultural waste impacts is for the Boundary Bay tributaries because most pollution complaints originate there, indicators such as fish kills occur there, and because Water Quality Objectives have been set for these areas. Relatively few complaints have been received regarding agricultural pollution in the Alouette system, so fewer research and enforcement resources have been directed there. Water Quality Objectives are under development that include the Alouette River. Once these have been adopted, monitoring resources will be divided so that more knowledge should result.

Table 5 SALMON ESCAPEMENTS TO STREAMS ENTERING BOUNDARY BAY

Year	Campbell River			Serpentine River		Nicomekl River
	Chinook	Chum	Coho	Chinook	Coho	Coho
1951	N/R	750	3500	N/R	1500	1500
1952	N/R	1500	1500	N/R	1500	3500
1953	N/R	1500	1500	N/R	1500	3500
1954	N/R	N/O	750	N/R	750	3500
1955	N/R	200	400	N/R	750	1500
1956	N/R	200	750	N/R	1500	1500
1957	N/R	75	400	N/R	400	750
1958	N/R	75	400	N/R	750	750
1959	N/R	25	750	N/R	1500	750
1960	N/R	75	400	N/R	400	750
1961	N/R	75	400	N/R	400	3500
1962	N/R	25	200	N/R	400	200
1963	N/R	25	400	N/R	400	200
1964	N/R	75	750	N/R	750	7500
1965	N/R	25	200	N/R	400	200
1966	N/R	75	400	N/R	400	400
1967	N/R	N/R	200	N/R	200	400
1968	N/R	N/R	200	N/R	200	200
1969	N/R	25	200	N/R	75	75
1970	N/R	200	750	N/R	750	1500
1971	N/R	200	750	N/R	3500	3500
1972	N/R	400	7500	N/R	1500	1500
1973	N/R	200	3500	N/R	1500	3500
1974	N/R	250	3500	N/R	2000	2500
1975	N/R	400	2200	N/R	2800	3500
1976	N/R	200	3500	N/R	3500	3500
1977	N/R	100	500	N/R	3000	3500
1978	25	50	1500	N/R	4500	600
1979	25	75	1500	N/R	1500	1500
1980	27a	200	1882a	N/R	500	1750
1981	113a	145a	1943a	2	1100	1000
1982	81a	205a	3898a	4	600	1200
1983	92a	376a	3083a	N/O	350	1000
1984	190a	766a	4182a	5	800	875
1985	194a	295a	4777a	N/O	325	600

N/R Not recorded
N/O Not observed
a Fence count, Semiahmoo Fish and Game Club
(Source: Farwell, et al.. 1987)

Table 6 FISH KILLS DUE TO LOW DISSOLVED OXYGEN LEVELS IN THE SERPENTINE RIVER, 1980 - 1984

Date	Fish Killed (coho salmon)	Rainfall (mm) (previous 7 days)
October 2, 1980	300-800	19.6
October 9, 1983	50	14.0
October 31, 1983	150	49.6
October 19, 1984	12	10.9
October 28, 1984	470	41.6

(Source: Moore, 1989)

Table 7 WATER AND EFFLUENT QUALITY DATABASE, ENVIRONMENTAL PROTECTION, MOE

Reports:

Serpentine River Dissolved Oxygen Survey 1980 - 1984
- About 12 stations
- Dissolved oxygen/temperature data (1981-84)
- Plankton taxonomy to 1983
- Latimer Creek water chemistry survey
- Water chemistry of agricultural runoff discharges (1981)

In-Stream Aeration of the Serpentine River. 1986
- U.B.C. Thesis by Chris Town
- Aerator design and construction
- Water quality survey

Impacts of Agricultural Drainage and an Assessment of Diffused Aeration in the Serpentine River, B.C. 1988
- U.B.C. Thesis by Tom Robinson
- Aerator effectiveness
- Water quality survey

Lower Fraser Valley Agricultural Waste Management Survey. 1987
- By Karen Hutton
- Water quality survey
- Farms inventory, Sumas River

Dissolved Oxygen Demand in the Serpentine River Using *in situ* Test Chambers. 1988.
- By W.F.A. Duncan.
- Assessed the cause of lowered DO levels using Production/Respiration chambers
- Some water chemistry from rivers and ditches

Data:

1982 - 1983 Campbell and Nicomekl River water chemistry

1984 Serpentine River water chemistry and plankton
- in some ditches as well
- hydrolab survey (carried out by Environment Canada)

1986 Serpentine River water chemistry
- in some ditches as well
- long term BOD survey (Manometric BOD unit)
- Dairy Farm Inventory in lower Serpentine watershed

1988, 1989, 1990 Water Quality Objectives Monitoring
- Boundary Bay tributaries
- September to November

Provisional Water Quality Objectives for Boundary Bay and its tributaries were approved in February 1988 (Swain and Holms, 1988). They were set to protect aquatic life and recreation in Boundary Bay, and aquatic life, wildlife, irrigation, and livestock watering in the tributaries. Monitoring of these objectives has generally taken place September to November, which is the critical period for returning salmon, and a time when oxygen levels may be stressed due to field runoff and dying algae blooms. The attainment of the objectives in 1988 and 1989 was generally mixed (table 8). Agricultural wastes, along with stormwater runoff from the basin highlands, are the main reason objectives are not attained.

Table 8 THE ATTAINMENT OF WATER QUALITY OBJECTIVES, BOUNDARY BAY AND ITS TRIBUTARIES

Objective	Campbell River and tributaries		Mahood, Hyland, and Latimer Creeks		Serpentine River		Nicomekl River		Anderson and Murray Creeks		Boundary Bay	
	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989
Fecal Coliforms	◊	◊	◊	◊	•	•	•	•	•	•	•	◊
Suspended solids	◊	◊	◊	◊	•	◊	◊	◊	•	◊	-	-
Substrate sedimentation	?	o	?	◊	?	•	?	-	◊	◊	?	-
Turbidity	◊	◊	◊	◊	◊	◊	◊	◊	◊	◊	-	-
Ammonia nitrogen	•	•	•	•	•	•	•	•	•	•	na	
Nitrite nitrogen	◊	◊	•	◊	o	◊	◊	◊	◊	•	na	
Chlorophyll-a	-	-	-	•	-	-	-	-	-	-	na	
Dissolved oxygen	◊	◊	•	◊	◊	◊	◊	◊	•	◊	•	◊
pH	•	•	•	◊	◊	◊	◊	•	•	•	na	
Total lead	na		na		na		•	•	na		na	
PCBs in water	na		?	?	?	?	na		na		na	
PCBs in sediment	na		-	•	-	•	na		na		•	•
PCBs in fish	na		-	-	-	-	na		na		na	

NOTES: (Source: B.C. Ministry of Environment, 1989a; 1990)

- • Objective met
- o Objective not met
- ◊ Mixed results, objective met at some parts of reach, or at some times, but not at others
- - Not checked
- ? Indefinite result, may be due to too few samples, or to a detection limit above the objective
- na not applicable
- PCBs Polychlorinated biphenyls

Provisional water quality objectives for the Fraser River from Kanaka Creek to the mouth were introduced in November 1985 (Swain and Holms, 1985). The designated water uses for the Main Stem, North and Middle Arms, and the Main Arm are for the protection of aquatic life, wildlife, recreation, livestock watering, and irrigation. Where monitoring data indicate a definite result, the objective was generally attained (table 9). Domestic, industrial, and stormwater effluents play a greater role in lack of attainment than do agricultural wastes.

Table 9 THE ATTAINMENT OF WATER QUALITY OBJECTIVES, FRASER RIVER ESTUARY

Objective	North Arm		Main Arm		Main Stem	
	1988	1989	1988	1989	1988	1989
Fecal Coliforms	•	•	◊	◊	•	•
Suspended solids	-	◊	na		na	
Ammonia nitrogen	?	•	•	•	na	
Chlorine residues	na		-	•	na	
Dissolved oxygen	•	◊	•	◊	•	•
pH	•	◊	•	•	-	•
Total copper	?	◊	•	◊	na	
Total lead	?	•	•	•	na	
Total zinc	?	•	•	•	na	
CPs in water	?	?	?	•	?	•
CPs in sediment	?	o	?	o	?	•
CPs in fish	•	-	•	-	•	-
PCBs in sediment	?	•	?	•	•	•
PCBs in fish	•	-	•	-	•	-

NOTES:

- • Objective met
- o Objective not met
- ◊ Mixed results, objective met at some parts of reach, or at some times, but not at others
- - Not checked
- ? Indefinite result, may be due to too few samples, or to a detection limit above the objective
- na not applicable
- CPs Chlorophenols
- PCBs Polychlorinated biphenyls

(Source: B.C. Ministry of Environment, 1989a; 1990)

Agricultural Waste Management Legislation and Programs

The primary provincial vehicle for pollution control is the Waste Management Act (SBC 1982 Chap. 41), which generally prohibits the introduction of waste into the environment unless in compliance with a permit. The permit process is defined in the Waste Management Regulation (B.C. Reg. 432/82) which allows a permit-holding exemption for agriculture. Section 11 of the regulation sets out a Class B: agricultural type exemption for "all discharges of plant and animal waste emanating from traditional farming operations which are managed and applied in a reasonable manner as organic fertilizers to promote crop production, and all discharges or emissions into the air from traditional farming operations." A Class C: industrial type exemption is set out for "all discharges of wood waste which, to the satisfaction of the Regional Waste Manager, are managed and applied in a reasonable manner, as plant mulch, soil conditioner, animal bedding and for ground cover and foundation material at equestrian facilities and construction sites." Though a permit is not required, if a serious environmental impact is occurring because of an agricultural practice, a pollution abatement order requiring the farmer to initiate remedial measures can be issued by Environmental Protection, MOE. Anyone in contravention of an order is liable to a penalty not exceeding $300,000.

Recently, the agricultural exemptions have come under review because of concerns regarding the environmental impact of agricultural wastes and the difficulty in determining the farming practices required for acceptable waste management. There has been no definition or explanation of "traditional farming operation" or what is a "reasonable manner" when handling farm wastes.

An Agricultural Waste Management Committee was established in 1988 with representation from the B.C. Ministry of Environment, B.C. Ministry of Agriculture and Fisheries, B.C. Federation of Agriculture, the federal Department of Fisheries and Oceans, and the Greater Vancouver Regional District. The committee has produced a draft Agricultural Waste Control Regulation to the Waste Management Act that will allow for the continuation of permit exemptions subject to observed waste management standards. In addition, the committee is developing a Code of Agricultural Practice for Waste Management that will detail the practical and environmentally sound standards required to retain the exemption. The regulation is intended to be implemented early in 1991 following consultation with the agricultural industry commodity groups. Following promulgation of the Agricultural Waste Control Regulation, farm operators will have to meet the codes in order to operate without a Waste Management Permit from the Ministry of Environment.

Complaints regarding agricultural waste are normally referred to the Agricultural Environmental Services (AES) program which is co-sponsored by the B.C. Federation of Agriculture and the Ministry of Agriculture and Fisheries. This program was formed in 1975, and essentially involves a peer group inspection of the suspect operation. Peer group inspection teams are usually well equipped to advise farmers of alternate, more acceptable, and practical waste management methods.

The AES program has not always produced satisfactory results, however, as in some cases the waste management concern is not dealt with effectively. Reasons for this include inadequate explanation of the environmental concern by ministry staff, lack of understanding by the farmer or inspector, lack of value attached to the concern by the farmer or inspector, incomplete remediation of the problem by the recommended measures, incomplete understanding of the recommended engineering options, lack of a viable, practical solution, and insufficient follow-up by ministry staff or inspectors due to time limitations or other priorities (Moore, 1989).

The B.C. Federation of Agriculture is proposing a "revised and revitalized" AES program in light of the Agricultural Waste Control Regulation and the attendant Code of Agricultural Practice for Waste Management. An Agricultural Environmental Protection Council is to be established with a mandate to set standards and monitor performance. Waste producers need to avoid under-valuing waste management and environmental protection, and to be aware of the appropriate practices that will reduce existing impacts and prevent future concerns. The AES can inform farmers of the code of practice, and how to incorporate it into their activities. Agricultural waste inventories conducted by MOE Environmental Protection staff and contractors have found that many impacts are not reported through the complaint process. Ultimately, the attitude of the waste producer, and the approach normally taken by the producer towards waste management, may be the most significant protection afforded the environment (Moore, 1989).

The B.C. Ministry of Agriculture and Fisheries sponsors a Best Agricultural Waste Management Plan program. In this program, new or existing commercial livestock producers and greenhouse operators who wish to address pollution concerns may apply to the ministry for a waste management audit of their operation. An engineering specialist will visit the farm with the producer and jointly develop the Best Waste Management Plan to address identified or potential problems caused by livestock manure, dead animals and afterbirth, livestock feed, dairy milk house waste, yard runoff, and greenhouse waste water. Pesticide pollution concerns are not included (see Pesticide section). Implementing the suggestions made in the Best

Agricultural Waste Management Plan will bring the operation into compliance to the Code of Agricultural Practice for Waste Management mentioned above.

The Ministry of Agriculture and Fisheries, in cooperation with the B.C. Federation of Agriculture, is revising and expanding a series of environmental guidelines for each commodity group. The guidelines will explain the structures and management practices required to meet the Code of Agricultural Practice for Waste Management and protect the environment.

The Agriculture Protection Act (SBC 1989 Chap. 19), assented to 28 June 1989, is intended to protect farmers from nuisance suits providing the farmer operates under acceptable agricultural practices. Expected practices include meeting the Code of Agricultural Practice for Waste Management as well as any Agriculture Protection Act regulations. The act is expected to be proclaimed once the code has been established.

The Agricultural Land Development Assistance (ALDA) program, administered by the Ministry of Agriculture and Fisheries, provides loans to help farmers adopt new technology to improve their competitiveness and to protect the environment. Other loan and subsidiary programs are also in place.

Sanitary regulations under the Health Act (RSBC 1979 Chap. 161) may be applied to poultry and livestock operations affecting management of manure and wastewaters. Covered under these regulations are nuisance abatement, dead animal disposal, location of offensive operations, protection of the public from conditions injurious to health, and prevention of stream pollution.

The Environmental Management Act (SBC 1981 Chap. 14) identifies the powers of the Minister of Environment in preventing detrimental impacts to the environment. Where the minister considers that an environmental emergency exists, as from a pesticide spill for example, he may order that the hazard be reduced. Authority for certain management programs, as for preparation of the Water Quality Objectives mentioned above, is also drawn from this act.

Federally, the Department of Agriculture has established a National Soil Conservation Program, which allows federal-provincial agreements for soil and water conservation. A Canada-British Columbia Accord on Soil and Water Conservation and Development was signed early in 1990. The Canada-British Columbia Soil Conservation Agreement, with the theme "Our Soil . . . Our Future," is the first agreement under the accord. Activities addressing

two major issues, soil nutrient conservation and soil conservation, will be conducted under three sub-programs: technology transfer, state of the environment, and awareness and education. Among the most urgent soil conservation issues to be addressed are animal waste and field chemicals management.

The Fisheries Act (RSC 1985 Ch F-14) is the principal federal legislation for protection of water quality and fish habitat. It applies to all waters frequented by fish. Sections 34 to 42 constitute the pollution prevention provisions of the act, serving to prevent contamination of fisheries waterbodies by prohibiting the deposition of deleterious substances, and prohibiting any work or undertaking that may result in harmful alteration, disruption, or destruction of fish habitat. The act can be contravened by agricultural activities that generate substances that may be deposited in fish-frequented waters. A deleterious substance is one that is toxic to fish or contains substances that will degrade water for fish. The use of wastes to fill in sloughs, marshes, and foreshore areas can also contravene the act by harmfully altering fish habitat.

Another federal act that may be invoked to deal with the introduction of deleterious substances to the environment is the Migratory Birds Convention Act (RSC 1985 Chap. M-7) which is administered by the Canadian Wildlife Service, DOE. Under this act and its regulations it is an offence to release oil or any other substance harmful to migratory birds into waters or areas frequented by migratory birds.

Normally, the federal government administers its pollution concerns through the provincial Ministry of Environment permit system. As traditional agricultural activities are exempt from the permit process, however, the procedure has been to coordinate with provincial officials when a complaint is received, and ensure federal concerns are addressed if a pollution abatement order is issued. Federal officials may also act unilaterally on need.

Other acts regulate the use of products that may have environmental impacts. These are discussed in the context of specific areas below.

Chemical Fertilizers

Nature and Magnitude of the Problem

Chemical fertilizers are a mixture of any or all of nitrogen, phosphorus, potassium, and inert ingredients. Properly used, they enhance crop production, and also reduce pollution through less runoff, erosion, and leaching. The environmental fate of fertilizer constituents varies depending on the nutrient type, soil conditions, weather conditions, and agricultural

practices. Properly applied fertilizers under normal conditions should result in negligible leaching or residue runoff. Under some conditions, however, nitrogen is susceptible to significant leaching, and phosphorus absorbed on soil particles may be transported by runoff to a significant extent. Potassium is usually not a concern.

Nitrogen, usually in the form of nitrate, is a concern in groundwater used as drinking water as it can lead to potential human health problems, particularly methemoglobinemia in infants. In experiments at Agassiz, Kowalenko (1989) found that nitrogen applied at a rate equivalent to 120 kg/ha does not leach beyond the root zone during the growing season, but all residual NO_3^--N is leached over the winter.

Chemical fertilizer applied in the Fraser River Estuary area in 1985 totalled 10,815 tonnes (table 10). Only in Pitt Meadows, an area drained by the Alouette and Pitt Rivers, are chemical fertilizer sources of nitrogen applied at a rate that is in excess of crop needs (Van Kleeck, In Prep.).

Table 10 COMMERCIAL FERTILIZER APPLIED IN FRASER ESTUARY AREA, 1985

Municipality	Farms reporting	Hectares	Tonnes
Burnaby	47	80	267
Delta	117	5,084	3,544
Langley	394	3,560	1,727
Maple Ridge	61	546	279
Pitt Meadows	102	1,577	929
Richmond	203	2,293	1,427
Surrey	230	4,074	2,642
TOTAL	**1,154**	**17,214**	**10,815**

(Source: Statistics Canada, 1987)

Management

The federal Fertilizers Act (RSC 1985 Chap. F-10) and its regulations, administered by Agriculture Canada, require that all fertilizers and supplements used in Canada be registered, and prescribes standards for composition, packaging, and labelling. The use of harmful ingredients in fertilizer is prohibited except under certain conditions.

The B.C. Ministry of Agriculture and Fisheries recommends best practices for fertilizer application rates, timing, and type to be used with specific crops and soil conditions. Agriculture Canada, at research stations such as at Agassiz, investigates fertilizer effects, optimum application rates, environmental pathways, and the environmental fate of residues.

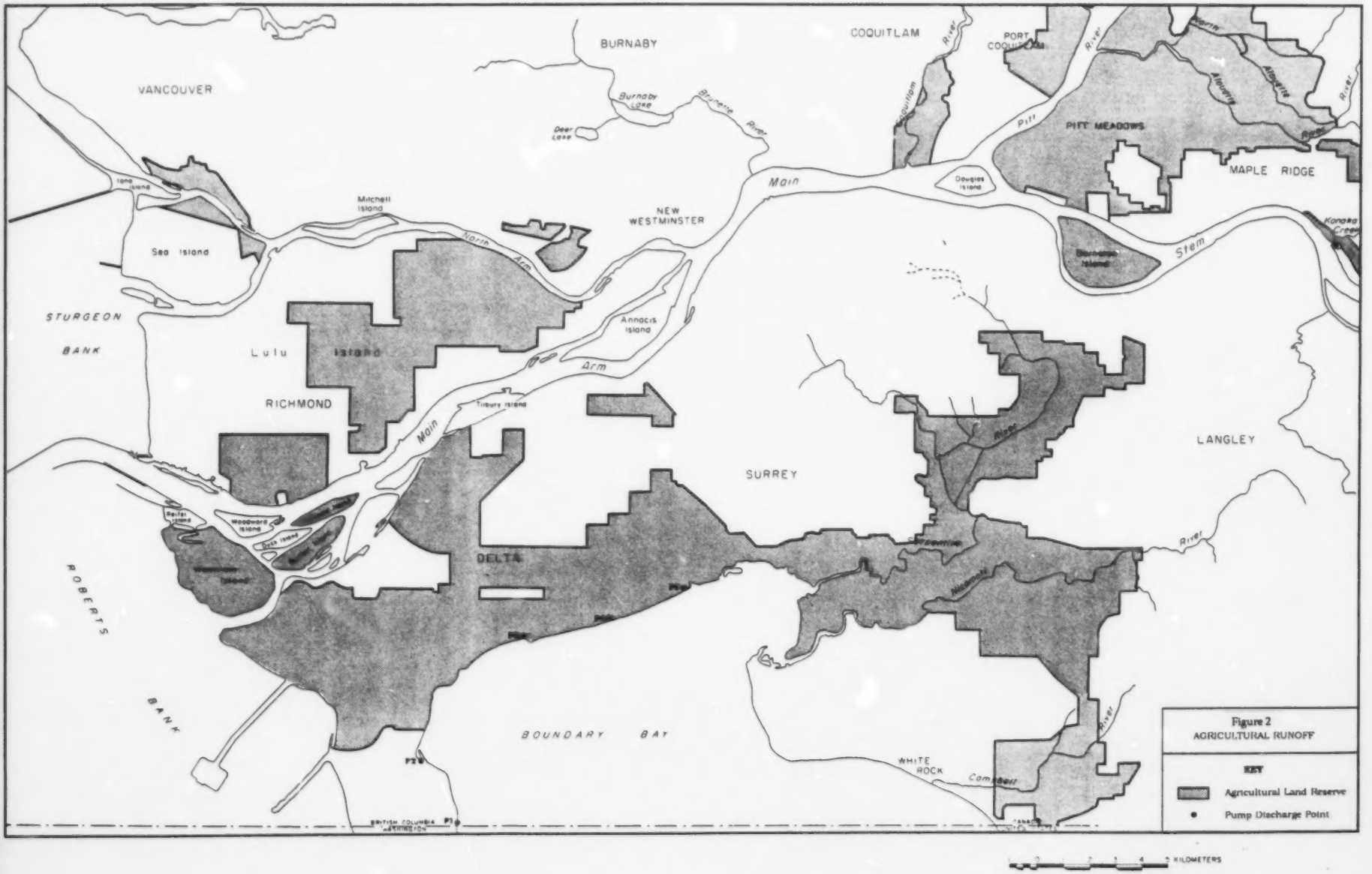


Figure 2
AGRICULTURAL RUNOFF

KEY

- Agricultural Land Reserve
- Pump Discharge Point

Actions Required

Chemical fertilizers are applied when needed, and nutrients are generally taken up by the crops fertilized. Except in a few areas, there is little environmental impact from fertilizer residues. Actions required include:

- Continued awareness initiatives such as the Best Management Practices to inform farm operators of the optimum application rates to avoid overfertilization
- Investigation of areas such as Pitt Meadows where overfertilization occurs, and where fertilizer residues may be causing environmental impacts

Animal Manure

Nature and Magnitude of the Problem

Manure, or livestock waste, may be solid, semi-solid, or liquid depending on the type of animal, its age, and its diet. Generally it is solids containing some liquid and a high concentration of BOD, pathogens, and nutrients. Manure quality is affected by its handling method, it may contain varying amounts of bedding material or spilled feed. When spread on fields at appropriate application rates, manure serves as a valuable fertilizer and soil conditioner. In this case, it is not a pollutant.

Two trends have resulted in the production of excess manure, however, and excess manure leads to potential environmental contamination. One trend is increased use of chemical fertilizers rather than manure. Reasons for this trend include the need to apply nutrients at optimum spring planting periods, the need for a consistent, optimum fertilizer formula, and the inexpensiveness of chemical fertilizers that provide this. Spreading manure on a once per year basis is prohibitively expensive due to storage needs. Animal manure is unable to provide a source of consistent crop nutrients as its nitrogen and phosphorus content varies by kind of animal, kind of feed, kind of bedding material, storage, evaporation, leaching, and application rate.

The second trend is to more animals per acre or farm, with some farms housing animals in barns year-round. There is a lack of sufficient acreage for optimum manure spreading. Farms may not grow crops which would require manure fertilizer. In short, manures cannot be managed as fertilizers rather than wastes if there is not enough on-farm storage capacity, or if there is not enough land.

Exacerbating excess manure problems are the associated disposal practices. Manure containment facilities are commonly emptied in the fall onto newly harvested fields. Manure BOD is then flushed from fields or drainage ditches during fall storms, corresponding to the algae die-off period (Town and Mavinic, 1986). Frozen, saturated, bare, compacted, or steeply sloped soils are all susceptible to increased runoff. Manure spread under these conditions can contaminate receiving waters.

Manure Contaminant Loadings

Data required to estimate total loadings of BOD, COD, pathogens, and nutrients to receiving waters in the FREMP area as a consequence of manure contaminated agricultural runoff are generally lacking. The British Columbia Census of Agriculture (Statistics Canada, 1987) provides animal numbers for 3 June 1986 (table 11). The values for manure produced per animal and manure constituents are given by several sources (tables 12 - 13; see also Bangay, 1977; Loehr, 1984; Overcash, et al., 1983; Tolganades, 1986). The total amountof manure, oxygen demanding substances, and nutrients can be estimated by applying literature values to the animal population of the FREMP area (table 14). These estimates are inexact because animal numbers may not match those of the census snapshot and because manure production and quality varies by the animal's species, age, diet, and handling methods. Literature values vary for this reason, and the actual values for the FREMP area may differ also.

Table 11 ANIMAL CENSUS, FRASER RIVER ESTUARY AREA, 1986

Animal	Burnaby	Delta	Langley	Maple Ridge	Pitt Meadows	Richmond	Surrey	TOTAL
Cattle	•	6,343	15,703	3,582	5,473	1,662[1]	14,407	62,129
Pigs	x	x	14,073	147	47	11	6,608	20,886
Sheep	•	740	5,111	844	170	279[1]	937	10,593
Horses	96	732	3,273	351	106	380	1,235	6,173
Goats	0	47	577	126	34	51	282	1,117
Rabbits	•	73	1,172	1,690	102	575[1]	1,835	10,623
Mink	0	0	86,256	x	0	0	42,924	129,180
Chickens	•	1,686	1,573,800	78,089	2,778	< 95,018[1]	732,500	3,339,034
Turkeys	0	•	206,438	x	54	< 22,076[3]	102,708	529,963
Other poultry	•	•	6,766	4,172	x	4,424[2]	2,446	57,626

Notes:
x Data suppressed for confidentiality
• See Richmond
[1] Includes Burnaby
[2] Includes Burnaby and Delta
[3] Includes Delta
(Source: Statistics Canada, 1987)

Table 12 FRESH MANURE PRODUCTION AND CHARACTERISTICS

Animal		Total Manure	Total Solids	Volatile Solids	BOD_5	COD	Nitrogen Kjeldahl	Nitrogen Ammonia	Phosphorus Total	Phosphorus Ortho	Potassium
Dairy	kg/d/lwt[1]	86	12	10	1.6	11	0.45	0.079	0.094	0.061	0.29
640 kg[2]	std deviation[1]	17	2.7	0.79	0.48	2.4	0.096	0.083	0.024	0.0058	0.094
	kg/day/an[3]	55	7.7	6.4	1.0	7.0	0.29	0.05	0.06	0.039	0.19
	kg/yr/an[3]	20,090	2,803	2,336	374	2,570	105	18	22	14	68
Beef	kg/d/lwt	58	8.5	7.2	1.6	7.8	0.34	0.086	0.092	0.03	0.21
360 kg	std deviation	17	2.6	0.57	0.75	2.7	0.073	0.052	0.027	na	0.061
	kg/day/an	21	3.1	2.6	0.58	2.8	0.12	0.03	0.033	0.011	0.076
	kg/yr/an	7,621	1,117	946	210	1,025	44	11	12	3.9	28
Veal	kg/d/lwt	62	5.2	2.3	1.7	5.3	0.27	0.12	0.066	na	0.28
91 kg	std deviation	24	2.1	na	na	na	0.045	0.016	0.011	na	0.1
	kg/day/an	5.6	0.47	0.21	0.15	0.48	0.025	0.011	0.006	na	0.025
	kg/yr/an	2,059	173	76	56	176	9.0	4.0	2.2	na	9.3
Swine	kg/d/lwt	84	11	8.5	3.1	8.4	0.52	0.29	0.18	0.12	0.29
61 kg	std deviation	21	6.3	0.66	0.72	3.7	0.21	0.1	0.1	na	na
	kg/day/an	5.1	0.67	0.52	0.19	0.51	0.03	0.018	0.011	0.007	0.018
	kg/yr/an	1,870	245	189	69	187	12	6.5	4.0	2.7	6.5
Sheep	kg/d/lwt	40	11	9.2	1.2	11	0.42	na	0.087	0.032	0.32
27 kg	std deviation	11	3.5	0.31	0.47	2.5	0.11	na	0.03	0.014	0.11
	kg/day/an	1.1	0.3	0.25	0.03	0.30	0.01	na	0.002	0.001	0.009
	kg/yr/an	394	108	91	12	108	4.1	na	0.86	0.32	3.2
Goat	kg/d/lwt	41	13	na	na	na	0.45	na	0.11	na	0.31
64 kg	std deviation	8.6	1	na	na	na	0.12	na	0.016	na	0.14
	kg/day/an	2.6	0.83	na	na	na	0.03	na	0.007	na	0.02
	kg/yr/an	958	304	na	na	na	11	na	2.6	na	7.2
Horse	kg/d/lwt	51	15	10	1.7	na	0.3	na	0.071	0.019	0.25
450 kg	std deviation	7.2	4.4	3.7	0.23	na	0.063	na	0.026	0.007	0.091
	kg/day/an	23	6.8	4.5	0.77	na	0.14	na	0.03	0.01	0.11
	kg/yr/an	8,377	2,464	1,643	2.79	na	49	na	12	3.1	41
Layer	kg/d/lwt	64	16	12	3.3	11	0.84	0.21	0.3	0.092	0.3
..8 kg	std deviation	19	4.3	0.84	0.91	2.7	0.22	0.18	0.081	0.016	0.072
	kg/day/an	0.12	0.03	0.02	0.006	0.02	0.002	0.0003	0.001	0.0002	0.0005
	kg/yr/an	42	11	7.9	2.2	7.2	0.55	0.14	0.53	0.06	0.20
Broiler	kg/d/lwt	85	22	17	na	16	1.1	na	0.3	na	0.4
0.9 kg	std deviation	13	1.4	1.2	na	1.8	0.24	na	0.053	na	0.064
	kg/day/an	0.08	0.02	0.02	na	0.01	0.001	na	0.003	na	0.0004
	kg/yr/an	28	7.2	5.6	na	5.3	0.36	na	0.10	na	0.13
Turkey	kg/d/lwt	47	12	9.1	2.1	9.3	0.62	0.08	0.23	na	0.24
6.8 kg	std deviation	13	3.4	1.3	0.46	1.2	0.13	0.018	0.093	na	0.08
	kg/day/an	0.32	0.08	0.06	0.014	0.06	0.004	0.0005	0.002	na	0.002
	kg/yr/an	117	30	23	5.2	23	1.54	0.20	0.57	na	0.60
Duck	kg/d/lwt	110	31	19	4.5	27	1.5	na	0.54	0.25	0.71
1.4 kg	std deviation	na	15	na	na	na	0.54	na	0.21	na	0.34
	kg/day/an	0.15	0.04	0.03	0.01	0.04	0.002	na	0.001	0.0004	0.001
	kg/yr/an	56	16	9.7	2.3	14	0.77	na	0.28	0.13	0.36

NOTES: (Source: American Society of Agricultural Engineers, 1989)

1 Mean and standard deviation per 1000 kg live animal mass per day

2 Typical live animal mass

3 kilograms per day and per year per average animal

na not available

These data are combined from a wide base of published and unpublished information. Mean values for each parameter are determined by an arithmetic average consisting of one data point per source per year. Actual values vary due to differences in animal diet, age, usage, productivity, and management. Site specific data, where available, should be considered before the mean values presented here.

Table 13 ANIMAL MANURE NUTRIENT COMPOSITION

Animal	Manure (L/day/animal)	Manure	Nitrogen	Phosphorus	Potassium
		(kg/year/animal)*			
Beef/Dairy Cattle					
0 - 3 mo	5.4	1,971	11.4	1.20	0.02
0 - 6 mo	7.1	2,592	15.0	1.58	0.03
Beef feeder/Dairy heifer					
6 - 15 mo	14.2	5,183	30.1	3.16	0.06
15 - 24 mo	21.2	7,738	44.9	4.72	0.08
Beef cows	28.3	10,330	59.9	6.3	0.11
Dairy cow	45.3	16,535	95.9	10.1	0.18
Pigs					
3 - 6 weeks	1.1	402	2.29	0.60	1.41
8 - 22 weeks	5.1	1,862	10.6	2.79	6.52
12 - 16 weeks	5.1	1,862	10.6	2.79	6.52
20 - 22 weeks	9.1	3,322	18.9	4.98	11.6
Sows	11.3	4,125	23.5	6.19	14.4
Sheep (ewes)	2.8	1,022	9.68	1.64	8.48
Horses	26	9,490	67.4	10.4	44.6
Chicken					
Broiler	0.08	29	0.43	0.15	0.12
Layer	0.14	51	0.75	0.3	0.20
Turkeys					
Broiler	0.13	47	0.70	0.24	0.19
Breeder	0.34	124	1.82	0.62	0.50

* Assuming 1 L of manure weighs 1 kg

Table 14 ESTIMATED TOTAL ANNUAL PRODUCTION OF ANIMAL WASTE, OXYGEN DEMANDING SUBSTANCES, AND NUTRIENTS, FREMP AREA

Animal	Total Waste	BOD	COD	Nitrogen	Phosphorus	Potassium
			(kg/year)			
Cattle	400,042,865	9,472,947	44,005,521	2,320,307	244,738	4,314
Pigs	69,341,520	2,130,372	6,098,712	394,745	104,430	242,278
Sheep	6,353,596	148,044	1,874,424	50,884	9,930	53,003
Horses	58,581,770	1,463,001	11,716,354	416,060	64,199	275,316
Goats	746,200	19,188	149,240	12,287	2,904	8,042
Rabbits	190,645	4,902	38,129	na	na	na
Mink	4,521,300	na	na	na	na	na
Chickens	83,609,855	5,494,362	21,499,677	1,194,427	429,994	334,439
Turkeys	21,644,000	1,422,320	5,565,600	309,200	108,220	86,576
Other poultry	623,280	40,958	160,272	8,904	3,205	2,493
TOTAL	645,655,031	20,196,094	91,107,929	4,706,814	967,620	1,006,461
Annacis STP	106,503,710*	16,614,435	na	2,769,255	479,610	na

NOTES:

* Total discharge in m^3/year

Total waste production extrapolated from Table 13, as Table 12 does not give age-specific values. Cattle values are calculated from a breakdown of census figures not presented here. BOD and COD extrapolated from data in Loehr (1984)

A greater problem is in estimating what proportion of the oxygen demanding materials, pathogens, and nutrients generated reach receiving waters. The primary vehicle for this is field runoff although other mechanisms such as cattle access to streams also operate. Both the amount of runoff and the contaminant concentration in the runoff vary greatly depending on climate, weather conditions, soil type, and agricultural practices. For example, on arable land nitrogen losses from manure spreading are 30 to 50% when applied in spring and immediately worked into the soil, but 70% when applied in fall (Bertrand, 1989). For the Sumas watershed, Hutton (1987) assumed that 22% of manure ammonia applied in fall and winter would be lost, half of this entering receiving waters via contaminated runoff. If this holds for the FREMP area, then, as perhaps 25% of total nitrogen is ammonia, ammonia loading to the Fraser River estuary from agricultural runoff would be about 130,000 kg annually. Estimates of contaminant loadings for other manure constituents are not available.

Manure is the single largest agricultural waste concern in terms of the amount of waste generated, the amount used in farming practices, the amount of storage needed, and the magnitude of the environmental impact. The amount of manure produced in the FREMP area is not likely to decrease significantly in the short term.

Previously identified areas of concern include the lowland reaches of the Serpentine and Nicomekl Rivers and their respective uplands along Latimer and Murray Creeks. Equestrian facilities and dairy farms have been the major sources of manure wastes in these systems. These sources are also important in the Campbell River system, along with hog farm operations. Dairy farm concerns have generally centered on runoff from poorly maintained storage facilities, while the source of contaminated runoff from equestrian facilities is often open manure piles stored near a ditch or creek. Contaminated runoff from hog farms has in the past been caused by excessive applications to fields near ditches and streams.

The land-base available for manure spreading in certain areas in the Lower Fraser Valley is currently being examined by the Ministry of Agriculture and Fisheries (Van Kleeck, In Prep.). The nutrient needs of the crops grown on the fields available for manure spreading are compared to the amount of nutrients in the manure. Overall results for the Nicomekl/-Serpentine and Pitt Meadows areas indicate crop nutrient requirements are greater than that available in manure for nitrogen and potassium, but that there is an excess of phosphorus.

Management

The largest variable in controlling environmental contamination from manure handling lies in the farmers' agricultural practices. Hutton (1987) inventoried manure waste management practices for all Sumas watershed dairy, hog, and poultry farms. No similar inventory has been done for watersheds in the FREMP area. Results of the Sumas inventory indicate that dairy farmers use manure spreaders with storage facilities having a capacity of between 1 to 3 weeks to 8 months, the average being about 2.5 - 3 months. This means that during the rainy period October to March most farmers will have to empty their manure pits one or two times, going onto wet fields with heavy machinery. If the fields are already saturated with water, the manure will tend to run off. If the farmer cannot get on to his fields, the manure must be stockpiled, also leading to problems with runoff.

Use of manure as a fertilizer resource depends on adequate land availability. The land-base availability for manure spreading depends on the amount of manure generated, the nutrient requirements of the crops grown on the farm, storage facilities, distribution, and other factors. These factors vary by farm so that some farms have surplus land available for manure spreading and some have a shortfall. Good management requires that these surpluses and shortfalls be identified.

There has been extensive research into manure application to land in Europe. The Minister of Agriculture and Fisheries approved a technology transfer trip to Europe in June 1988 (Bertrand, 1989). The Puget Sound Water Quality Authority has investigated agricultural waste issues in the Puget Sound water shed (PSWQA, 1986), and incorporated a number of measures into their Water Quality Management Plan (PSWQA, 1990). One initiative is the Snohomish County Farm Water Quality Management Manual that covers three general concerns: confinement areas and manure handling, manure application to pasture, and pasture management and stream protection.

For the Lower Fraser Valley, an agricultural research and development consortium, Agriwaste Biosystems, has been formed to find a cost effective way to dispose of pig manure. The consortium is an alliance between pig producers and the scientific and engineering community funded by the industry and through government grants. The consortium's objective is the developing and applying of tested productive technology to pig farms of all sizes. Currently the consortium is arranging funding.

Action Required

Actions required include:

- Educate the various commodity groups by enhancing awareness of best management practices. Expand the Best Agricultural Waste Management Plan program, update and publicize environmental guidelines
- Continue development of innovative manure management techniques
- Inventory farms in the Fraser River estuary area to identify farm type, animal population, waste facilities, disposal practices, and land shortfalls for manure spreading. This will identify point sources of potentially significant impact
- Ensure that waste management concerns are addressed by those that are about to enter or expand livestock operations
- Identify on-farm surpluses or shortfalls of land available for optimal manure spreading and investigate storage and distribution systems to equalize these
- In the long term, consider limiting animal production according to the land base available for waste disposal

Pesticides

Nature and Magnitude of the Problem

Pesticides are toxic substances specifically designed to kill, repel, or regulate unwanted biological organisms such as weeds, insects, and rodents. Most agricultural use is of insecticides and herbicides, though nematicides, rodenticides, fungicides, fumigants, and disinfectants are also used. Prior to World War II pesticides were largely derived from naturally occurring minerals and plant products. Most of the synthetic, petroleum-based pesticides in use today have been developed since the 1930s. The following general discussion of pesticidal properties is largely drawn from PSWQA (1990) and MOE (1989b), and these can be consulted for more information.

Pesticides are made up of complex formulas consisting of active and inert ingredients, degradation products or metabolites of these ingredients, and product contaminants. Active ingredients are the primary agent intended to act on the target species. Over 500 active chemical ingredients are currently registered for use in Canada under the Pest Control Products Act (RSC 1985 Chap. P-9), and over 5,000 pesticide products are registered. There are numerous categories of active ingredients (table 15).

Table 15 CATEGORIES OF PESTICIDE ACTIVE INGREDIENTS

Organochlorines:	Organophosphates:	Carbamates:	Pyrethrins:
acrolein	azinphosmethyl	aldicarb	fenvalerate
aldrin	chloropyrifos	bendiocarb	
chlordane	diazinon	butylate	Pyridine-carboxylic acids:
DDT	disulfotor	carbaryl	triclopyr
dieldrin	fensulfothion	carbofuran	
dicofol	malathion	EPTC	Triazines:
endosulfan	methamidophos	methomyl	atrazine
endrin	methyl parathion	vernolate	metribuzin
heptachlor	parathion		simazine
lindane	phorate	Phenols:	toxaphene
methoxychlor		dinoseb	
mirex	Benzoic acids:		Uracils:
	dicamba	Phenoxyaliphatic acids:	bromacil
Anilides:		2,4-D	tebuthiuron
alachlor	Nitroanilines:	2,4,5-T	terbacil
	trifluralin		

Note: This is not a complete listing

The best known and most common pesticide active ingredient classes are the organochlorines, organophosphates, and carbamates. Organochlorines were used extensively through the 1960s because of their effectiveness and low cost. However, since the 1970s the registration of most organochlorines has been suspended, cancelled, or restricted by the federal government due to concerns about their environmental effects and human health risks. The organochlorine qualities of concern are their persistence, meaning they do not break down quickly in the environment, and their fat solubility, meaning they tend to accumulate in organisms exposed to them. Some organochlorines also biomagnify, meaning they become more concentrated in the tissues of animals higher up in the food chain.

Organophosphates, the largest single group, and carbamates are primarily insecticide active ingredients. Unlike the organochlorines, they do not tend to persist for long periods in the environment, and they are water, rather than fat, soluble, so they do not tend to bioaccumulate or biomagnify. They generally work by affecting the enzymes of the central nervous system. The organophosphates contain some of the most toxic pesticides used in Canada, e.g. parathion and phosdrin.

The organochlorines, organophosphates, and carbamates are primarily insecticides. Other categories of pesticidal active ingredients are used as herbicides or other pest specific biocides. Major classes include the anilides, the benzoic acids, the nitroanilines, the phenols, the phenoxyaliphatic acids, the pyrethrins and pyrethroids, the pyridine-carboxylic acids, the

triazines, and the uracils. These range in their toxicity to humans and in their environmental persistence. Generally, herbicides are less toxic than insecticides.

Inert ingredients are compounds other than the active agent that are intentionally added to the pesticide. Inerts are used as diluents, dyes, solvents, carriers, adsorbents/binding agents, and emulsifiers. Examples of inerts are water, oil, corn cob grits, coffee grounds, inorganic salts, wetting agents, benzene, carbon tetrachloride, chloroform, formaldehyde, and pentachlorophenol. The proportion of active and inert ingredients varies by product, and is the means by which pesticides sharing the same active ingredients differ. While not the primary agents that act on an identified pest, inerts may still be chemically or biologically active or toxic. The Pest Control Products Act also regulates inert ingredients.

Metabolites are substances produced by the breakdown or degradation of the parent compound. While the degradation of a pesticide compound usually renders the product less toxic and persistent, metabolites may be at least as persistent or more toxic than the parent compound. DDE and DDD are as persistent as their parent DDT. Dieldrin is more persistent and toxic than its parent aldrin. Malathion degrades to the more toxic diethyl fumarate; and endosulfan degrades to endosulfan sulfate which has greater persistence in soils, lower water solubility, and a greater toxicity. Generally, less is known of the environmental fate and toxicity of metabolites than for their parent compounds.

Contaminants in pesticides may result from imperfections in the pesticide manufacturing process. Low concentrations of dioxins and furans may be present in organochlorine pesticides. DDT has been found as a contaminant in dicofol.

Concerns regarding pesticide use rest on the toxicity of pesticide residues to non-target species. Acute toxicity refers to the concentration or dosage needed to kill an organism within a short time period. Acute effects also result when an organism is so affected by a pesticide that death occurs from another cause such as predation. Toxicity is measured in terms of the lethal concentration or dose required to kill 50% of the test population in a specific time period, usually 48 or 96 hours (48hr or 96hr LC_{50} or LD_{50}). Organochlorine LC_{50} values for fish species range from less than 1 to around 200 parts per billion (ppb). Some organophosphate and carbamate insecticides are also acutely toxic in the low parts per billion range. Acute toxicities of herbicides to aquatic species are generally about a few parts per million. Terrestrial species are particularly sensitive to organochlorine and organophosphate insecticides, with these compounds having typical LD_{50} values of 100 ppm. Birds and mammals are generally less sensitive to most herbicides and fungicides.

Pesticidal toxic effects may not be lethal, but may induce alteration of growth rates, reproduction, feeding behavior, and activity levels; the formation of tumors and birth defects; and genetic change in subsequent generations. These chronic toxicity effects are induced by concentration levels much lower than for acute effects. They often develop over relatively long time periods after exposure, and outward changes are very subtle. Consequently, safe, or threshold, levels of pesticides in the environment are difficult to determine. Theoretical safe levels may be below analytical detection limits.

Residues from agricultural pesticide use reach aquatic systems through runoff from fields, direct deposition in ditches or streams, accidental spills or improper storage, drift from aerial spraying, and contaminated groundwater connections to surface water. The rate at which this occurs depends in part on the mobility of the pesticide. Mobility, the potential for a pesticide to migrate from its point of application, is primarily affected by the soil adsorption characteristics of the pesticide. Pesticides that are strongly absorbed, or adhered to soil particles, are generally less mobile. Water soluble pesticides are apt to be less strongly adsorbed, and have a greater potential for surface water contamination. However, absorbed pesticides can be transported by soil movement or erosion.

Once in the environment, the fate of the compounds present in the product depend on their persistence and tendency to bioaccumulate. Persistence, or the potential for a pesticide to resist chemical, physical, and biological degradation, is affected by its concentration and structure, its water solubility, the amount of suspended particulate matter present, and the particle size and organic content of bottom sediments. Generally, pesticides do not remain in the water column unless attached to suspended particulate matter, and tend to attach to organic matter which settles out and accumulates in bottom sediments. The rate at which a pesticide bioaccumulates depends on its fat solubility. In general, the most persistent and bioaccumulative pesticides are the organochlorines.

Pesticide Impacts, Fraser River Estuary:

The pesticides of concern that have been tested for in the Fraser River estuary are azinphosmethyl, diazinon, dinoseb, endosulfan, and fensulfothion. Dinoseb is a herbicide, the others are insecticides. A monitoring survey was conducted from 1985 to 1987 to determine the levels of these five pesticides in selected farm ditches leading to the Lower Fraser, Nicomekl, and Sumas Rivers (Wan, 1989). During 1989 - 1990 a further study investigated the effect of dinoseb and endosulfan on the biota in the Nicomekl River (EVS, In Prep.).

Dinoseb was the only pesticide consistently found in ditch water, the others were not detected. In ditch sediments, endosulfan was consistently found and low levels of all pesticides were sporadically found. There was evidence that the levels of pesticides in ditch water shortly after application exceed the 96 hr LC_{50} values of fish and aquatic vertebrates, but generally, the impacts to salmonids and aquatic invertebrates of low levels of pesticides in sediments is not known (Wan, 1989).

The 1989 Boundary Bay sediment monitoring program (Swain and Walton, 1990) found organochlorine pesticides to be common generally in marine sediments, upstream from stormwater pump stations, and present in sediments from the three tributaries. The most common organochlorines were DDE, endosulfan, heptachlor, and heptachlor epoxide.

Areas of particular concern are the Serpentine and Nicomekl River watersheds and the Cresent Slough area off the Main Arm of the Fraser River. Here field runoff may concentrate pesticide residues in relatively small amounts of slow moving waters. Another area of concern is on the North Arm where pesticides used on cranberry farms may be washed into the estuary when flooded fields are drained following berry harvest.

Management

A considerable amount of pesticide legislation has been developed to protect human health, non-target plants and animals, and environmental quality. The primary federal pesticide legislation is the Pest Control Products Act (RSC 1985 Chap. P-9), which is administered by Agriculture Canada. The act requires that every pesticide product sold in Canada be registered, and that it meet prescribed packaging and labelling conditions. Data submissions for new pesticides are reviewed by specialists in Agriculture Canada, Health and Welfare Canada, Environment Canada, and Fisheries and Oceans Canada to ensure health and environmental impacts are acceptable. A pesticide may then be given full registration which is effective for 5 years. Pesticides registered before the evaluation now in place was implemented are being reviewed, and further studies required if necessary. Regulations under the act may describe the nomenclature, form, and composition of pesticide products, the conditions of their registration, manufacture, packaging, labelling, and advertisement, and provide for exemptions. A federal panel is currently reviewing the pesticide registration process.

In British Columbia, the Pesticide Control Act (RSBC 1979 Chap. 322) and its regulation (B.C. Reg. 319/81) apply to the sale, transport, storage, preparation, application, and disposal of pesticides. The act and regulation are administered by the Pesticide Control Branch,

Ministry of Environment. Pesticide use permits, required for pesticide use on public lands or on private land used for forestry, transportation, or public utilities, are not required for pesticide application to agricultural land. However, vendors and commercial applicators are required to obtain the appropriate licence or certificate. Commencing 1 January 1992, all persons purchasing and using "restricted" agricultural pesticides must be certified. The B.C. Federation of Agriculture, Ministry of Agriculture and Fisheries, and Ministry of Environment are sponsoring a home study course leading to certification.

The Pesticide Residues in Water Committee is an intergovernmental committee with representatives from Environment Canada, Agriculture Canada, Fisheries and Oceans Canada, Health and Welfare Canada, B.C. Ministry of Environment, B.C. Ministry of Agriculture and Fisheries, and B.C. Ministry of Health. Its role is to coordinate the sharing of data, information, and research about pesticides in British Columbia waters. Monitoring is undertaken by staff and contractors for the Water Quality Branch, Inland Waters, Environment Canada, and Environmental Protection, Environment Canada.

Action Required

While pesticide and crop specialists in the Ministry of Agriculture and Fisheries recommend pesticide use and quantities to farmers and other agricultural users, and while pesticide control officers in the Ministry of Environment, Pesticide Control Branch receive information from vendors regarding type and quantity of pesticides sold, there is no real summary of pesticide use in the area. Even if the amounts of pesticides used were to be known, there is an incomplete understanding of the environmental fate and pathways of pesticide residues such that stream loadings could be predicted. This is because the factors or conditions affecting environmental fate are large and variable. Few monitoring studies have been undertaken, and not all pesticides of concern have been sampled for all areas.

Needed is:

- A summary of how much of the various pesticide active ingredients are spread on agricultural land by area and time of year
- Continued research into pesticide residues and their environmental fate, with concentration on pesticides currently in use
- Continued monitoring, with attention paid to higher priority pesticides. The pesticide residues in water database for the Fraser estuary is not very extensive. A coordinating committee such as the Pesticide Residues in Water Committee should

determine which pesticides present the highest risk of environmental impact and direct monitoring studies towards these

Wood Waste

Nature and Magnitude of the Problem

Wood waste includes sawdust, shavings, hog fuel, chips, bark, butt ends, and debris produced by shake and shingle, lumber, and plywood mills. About 20 - 50 % of delivered log volume fails to emerge as finished wood product (Slagle, 1976). Agricultural uses of wood waste are for plant mulch, soil conditioner, animal bedding, cranberry field berms, and for ground cover and foundation material at equestrian and track facilities. The main wood waste leachate concerns arise from its use in nurseries where it is used to surround potted plants, keeping them moist, in animal pens where it is used to soak up urine, and as berms around cranberry fields so they can be flooded for harvesting. Some farm operators use wood waste to level fields by removing topsoil, filling depressions with wood waste, and replacing the soil.

In contact with water, toxic extractives such as resin acids, tropolones, terpenes, tannin, and lignin are drawn into solution. Wood waste leachates also contain organic nutrients that may promote fungal growth. Wastes from wood exposed to antisapstain treatments may leach chlorophenols, chromium, arsenic, and copper. The characteristics of wood waste leachate varies considerably depending on the species and age of the tree, the part of the tree from which the wood waste originates, the particle size of the wood waste, and the amount of nonwood materials in the wood waste. It is the extractive constituents of wood that gives different species of trees their "personalities" (Slagle, 1976).

Wood waste leachate has several general characteristics. It is acidic due to the reaction with water of the CO_2 produced by wood decomposition as well as to wood extractives such as tannin and resin acids. It is a black liquid, probably due to the interaction of naturally dissolved iron with soluble tannins leached from the wood. It has an oily look, attributed to the terpenes dissolved from the wood. It has a high concentration of organic molecules in solution, as indicated by BOD_5, COD, and TOC values. As a consequence of the high organic load, the dissolved oxygen content of leachate is virtually zero. A final characteristic of wood waste leachate is its high iron content, which is partly mobilized from soil due to the leachate acidity.

The major impacts of wood waste leachate on surface waters are aesthetics and toxicity. Aesthetic problems include odor, water discoloration, foaming, flaky surface films, and

fungal/bacterial growth. Toxicity is mainly due to oxygen stress, but extractives such as the tropolones are also responsible. The level of toxicity will decline with time along with the reduction in percent extractives. Indirect impacts to fish may continue as fungal/bacterial growths on macroinvertebrates, fish gills, and eggs affect the organism's sensitivity to other factors such as disease.

Discharges of wood waste leachates from agricultural uses are largely confined to the Boundary Bay tributaries. Sources are often found to be landfilled depressions, stored piles of fresh bedding material, or stored piles of used bedding material mixed in with manure.

Management

Under the Waste Management Regulation of the Waste Management Act, a Class C: industrial type exemption is set out for discharges of wood waste that are applied in a reasonable manner as plant mulch, soil conditioner, animal bedding, and ground cover. The Code of Agricultural Practices for Waste Management states that the storage and use of wood waste on farms for acceptable purposes, which does not include landfilling, should be in a manner to prevent the runoff of leachates that cause pollution. Wood waste should be applied to the minimum depth necessary for the intended use.

Aged wood waste from which part of the extractives have been removed may still fulfill the required agricultural need while not producing an acutely toxic leachate. Aging can be achieved by running water through the wood waste under conditions that collect the resulting leachate for proper treatment. If feasible, a wood waste aging site can be developed to produce a safer product for industrial and agricultural uses; the leachate produced at the aging site could be treated prior to discharge (Moore, per. comm.).

No standards exist for agriculture uses of wood waste, although the City of Richmond has issued standards for discharge from wood waste fill/construction sites that are applicable to East Richmond. A wood waste leachate report is being produced by Environmental Protection, MOE (Hensel, In Prep.), and Fisheries and Oceans Canada is summarizing existing information.

Action Required

Detrimental environmental impacts arise from the wood waste leachates formed with water contact. It appears that no level of wood waste use is safe in terms of generating leachate amounts that do not result in toxic effects. Yet the use of wood waste is cost effective for

farmers and other agricultural operators that use it. Agricultural uses have also been a way of disposing of the large amounts of wood waste generated by sawmills in the area. In order to reduce the environmental impacts of wood waste leachates, it is necessary to reduce the amount of wood waste used, and to use wood waste in the best environmentally benign manner. Actions required include:

- Continue research into ways to reduce the amount of wood waste generated by the forest industry
- Explore alternate wood waste disposal methods
- Research alternatives for wood waste use
- Enhance awareness of Code of Agricultural Practices for Waste Management, and incorporate practices to minimize water contact with wood waste, as practical. The production of farm wood waste use guidelines should be investigated
- Verify that aged wood waste fulfills the required agricultural needs. Follow up by development of a wood waste aging and leachate treatment facility
- Develop standards regarding discharge from agricultural wood waste sites, that is, define the level of wood waste leachates causing a pollution problem. Agencies involved should form a committee to facilitate standards development

Silage Effluent

Nature and Magnitude of the Problem

Silage effluent is the liquid seepage that comes from the bottom or sides of a traditional silo or from the end of a silo bag. Most of this occurs in the first three weeks after ensiling. In the FREMP area, grasses are ensiled in June and September, corn is ensiled in September. About 1 m^3 of silage effluent is produced per silo.

Silage effluent is a high strength liquid, typically containing about 90,000 ppm BOD, about 3 times that of manure. While levels of inorganic nutrients are low, levels of organic nutrients are high enough to produce heavy bacterial or fungal growths in receiving waters.

Pollution problems can result if high strength silage effluent drains into ditches which in turn drain into streams. During or immediately following the September ensiling period, added oxygen stress could potentially be added to receiving water systems already under stress from other sources. Long term oxygen demand studies carried out in the Serpentine River watershed have shown silage effluent can play a significant role in determining receiving

water dissolved oxygen content. The mid- to lowland reaches of the Serpentine and Nicomekl systems have been subjected to silage effluent discharges in the past.

Management

Historically, no attention was paid to silage effluent. The best management practice recommended by Ministry of Agriculture and Fisheries engineers is to collect and discharge silage effluent to manure pits in cases where current practices allow silage effluent contamination of surface waters. Where current arrangements allow discharge of silage effluent to tile fields or to land with no runoff, no alteration is suggested.

Action Required

An environmental impact from silage effluent would occur if it were to drain directly into a ditch or stream that connected with salmon habitat, for example. September ensiling just precedes autumn salmon returns, so a fish kill could potentially result from silage effluent discharge. Actions required are:

- Farm operators with silos or silo bags need to be aware of the problem, and to incorporate the best management practice of handling silage effluent applicable to their operation. The producer needs to ensure that silage effluent does not enter receiving waters

Milk Parlor Effluent

Nature and Magnitude of the Problem

Milking center effluent may include manure deposited in the milking parlor, urine, udder washings, spilled milk, and equipment wash water. Contaminants include pathogens, oxygen demanding substances, and nutrients. The effluent is of relatively low strength, normally about 200 ppm of BOD. About 50 m^3/day is generated from the 1900 cows on 25 dairy farms in the Serpentine and Nicomekl watersheds.

Normal practice has been to discharge milking parlor effluent to septic tanks. However, the milk solids in the effluent do not settle, and tend to clog the tile field, causing the septic system to fail.

In receiving waters, these discharges can cause elevated bacteriological levels, nuisance growths, lowered dissolved oxygen levels, lowered pH, and toxic levels of ammonia and nitrite.

Impacts from milk parlor effluents have been noted in the mid- to lowland areas of the Serpentine River.

Management

The Livestock Industry Act (RSBC 1979 Chap. 243) and the Milk Industry Act (RSBC 1979 Chap.258) regulate the operation of livestock and dairy farms in B.C. Neither of these acts explicitly regulate waste management practices, though s. 9 of the Livestock Industry Act allows regulation of anything pertaining to the livestock industry. Milking parlor effluents are not explicitly mentioned in the Code of Agricultural Practices for Waste Management, but are included generally as agricultural wastes.

The best management practice recommended by B.C. Ministry of Agriculture and Fisheries engineers is to discharge the milking parlor effluent to manure pits for eventual spreading on fields.

Action Required

- Continue initiatives for farm operator awareness of the Code of Agricultural Practices for Waste Management and the associated best management practices

Animal Mortalities

Nature and Magnitude of the Problem

Animal mortalities are animals that have died and are not marketed for consumption. These include birds and animals dying from disease, old age, accident, or natural disaster. Improper disposal may cause surface or groundwater contamination by increasing bacteriological levels, encouraging nuisance growths, depressing dissolved oxygen levels in surface waters, and elevating ammonia and nitrite concentrations. Existing sites of concern are limited.

Management

Dead birds and animals are usually picked up and sent to a rendering plant, though disposal through burial, incineration, and composting also occurs. Only when the plant is overloaded and alternate disposal methods are used may potential environmental problems result. The Code of Agricultural Practice for Waste Management allows burial and

incineration if pollution does not occur. Composting is acceptable if the animals died on the agricultural operation they are being composted on and pollution does not result.

Action Required

- Continue initiatives for farm operator awareness of the Code of Agricultural Practices for Waste Management and the associated best management practices

Crop Residues

Nature and Magnitude of the Problem

Crop residues are vegetable waste matter remaining after harvesting of a crop. Included are stalks, leaves, vines, roots, and other plant parts. Normally, crop residues left to rot in the field will not result in a pollution problem. Only if stockpiled on the field will potential problems result, and then only if composting leachates can drain into a ditch or stream. No information is available to indicate the magnitude of this problem, but it is expected to be minor.

Potential areas of impact include the lowland vegetable farming areas in the Serpentine and Nicomekl River watersheds. Limited ditch sampling near vegetable crop residues revealed elevated organic carbon and organic nitrogen levels. However, the values were well below those from other agricultural waste sources (Moore, per. comm.).

Management

Most vegetable waste remains on the field where it is plowed under. Residues remaining after off-field processing are normally returned to the field and spread.

Action Required

- Continue initiatives for farm operator awareness of the Code of Agricultural Practices for Waste Management and the associated best management practices

Composting

Nature and Magnitude of the Problem

Composting is the oxidation of manure, dead animals, fish, crop residues and other decomposable material to humus and heat. It is bought about by the growth of bacteria,

actinomycetes, and fungi in a pile controlled for moisture content, carbon/nitrogen ratio, particle size and structure, aeration, temperature, mixing, acidity, and nutrients. The end product is a nutrient-rich, pathogen-free compost; the by-products are carbon dioxide, ammonia, sulfides, and water (Pos, 1982).

In the Lower Fraser Valley, the mushroom industry is a major user of composted horse manure, consuming about 15,000 m^3 per month. A co-op in Cloverdale produces much of this. A number of farms also produce compost.

Properly managed, neither the composting process or the compost itself result in environmental problems. Pollution concerns arise from compost leachates which result when the moisture content of the compost pile becomes too high. These leachates contain oxygen demanding substances and nitrogen. No characterization figures are available.

To date, mushroom composting sites have been the major sources of concern, with tributaries to Anderson Creek and the Serpentine River being impacted by resulting heavy fungal growths. Toxic impacts have also been recorded in the past.

Management

Best management practices recommend that composting be carried out under cover, avoiding excess moisture and drainage from rainfall.

Action Required

- Continue initiatives for farm operator awareness of the Code of Agricultural Practices for Waste Management and the associated best management practices

Soil Erosion

Nature and Magnitude of the Problem

Field runoff usually contains some concentration of soil particles in its suspended solids load. Erosion also occurs when a stream undermines its bank and soil slumps into the stream. In extreme cases, floods transport large quantities of soil into receiving waters and their channels.

Soil erosion has two potential contaminant problems. One is the presence of soil particles in water as sediments. These increase turbidity, decrease light penetration in the

water, adversely affect photosynthesis, and affect predator/prey relations through impacts on visibility. When sediments settle out, they may smother bottom vegetation, fish habitat, and fish eggs, and may also alter drainage and irrigation patterns. The second potential problem is the introduction of contaminants that are adsorbed to the soil particle. Nutrients such as phosphorus and pesticides such as DDT and parathion readily adsorb to soils and are relatively immobile unless the soil is also moved.

Management

The Soil Conservation Act (RSBC 1979 Chap. 391) regulates land filling and soil removal from agricultural land in an Agricultural Land Reserve. It does not say anything about natural erosion or preventive practices to avoid erosion. Likewise, the Drainage, Ditch and Dyking Act (RSBC 1979 Chap. 98) does not consider soil erosion prevention in any way. B.C. and Canada have signed a soil conservation agreement, part of the National Soil Conservation Program.

Best management practices include no-till planting or conservation tillage. There is a greater herbicide use with these practices, however. Alternate tilling methods can reduce soil loss to less than 5% compared to conventional tillage. Another effective soil conservation practice is the planting of a winter crop to maintain field cover, reducing runoff and the associated sediment load in the runoff.

The Ministry of Agriculture and Fisheries sponsors Best Soil Management Plans.

The Agricultural Land Development Assistance program offers low-interest loans for capital improvements including drainage systems, wind breaks, grassed waterways, channel stabilization, and minimum/zero-till equipment.

Action Required

- Education of producers regarding environmental impacts, agricultural impacts, and costs to the producer caused by soil loss
- Continue initiatives for farm operator awareness of soil conservation techniques and financial assistance available for soil conservation projects

Salinity

Nature and Magnitude of the Problem

Salinity refers to concentrations of calcium, magnesium, sodium, and potassium salts of chloride, sulfate, nitrate, and bicarbonate. The main sources of salinity in soil are weathering, inorganic fertilizers, organic amendments, and irrigation. Irrigation is a salt concentrating process as irrigation water always contains dissolved solids but water that evaporates contains no salts. The salts remain behind in the soil and the plants. Increased soil salinity affects root growth and crop yields. Salts can be leached below the root zone, but increased salinity in groundwater may affect quality of drinking water, and pose health risks.

A total of 5,520 ha are irrigated in the area surrounding the Fraser estuary (Statistics Canada, 1987; table 16). The primary source of irrigation water is withdrawal from surface waters. Licenses totalling 5.3 million m^3/year are administered by the Water Management Branch, Ministry of Environment. More is withdrawn from wells for irrigation purposes, but amounts have not been estimated.

Table 16 IRRIGATION IN THE FRASER ESTUARY AREA, 1985

Municipality	Farms reporting	Hectares
Burnaby	34	56
Delta	61	1,541
Langley	130	1,066
Maple Ridge	18	154
Pitt Meadows	42	415
Richmond	67	974
Surrey	122	1,313
TOTAL	474	5,519

(Source: Statistics Canada, 1987)

Salinity can be a concern for producers near the lowland reaches of the Serpentine and Nicomekl Rivers. The passive tidal gates on both rivers normally prevent saline water from entering the river systems, thereby providing a needed source of fresh irrigation water. When the gates are jammed open, as from debris floating down the rivers, saline water can enter the rivers with the rising tide. Salt water wedges may move considerable distances in the lowland reaches. Saline irrigation water is more a water management than a waste management problem, however.

Management

As the area has a moist climate , with a fair amount of runoff and leaching, and as few groundwater supplies are used for drinking or stock watering, salinity is not a problem in the Fraser estuary area except to the extent that saline water used for irrigation. Passive tidal gates on the Serpentine and Nicomekl Rivers were designed and are maintained by the Ministry of Environment.

Action Required

- Estimate groundwater withdrawals for irrigation

General Recommendations

Several common themes are evident from the different agricultural waste sources discussed above. A number of general recommendations can be made:

- **Expand the Best Agricultural Waste Management Plan program**

As each farm operation is different, the most effective way to optimize waste management of a particular operation is to produce a site-specific plan for particular farms. Currently, the Ministry of Agriculture and Fisheries can respond to all requests for a Best Agricultural Waste Management Plan, but there is a backlog. This voluntary program could be publicized and more resources allocated to it.

- **Offer economic incentives for compliance**

Some farm operators may be unable or not wish to incorporate measures to bring their operation into accord with the Agricultural Waste Control Regulation. Compliance can be encouraged through incentives such as Agricultural Land Development Assistance (ALDA) loans or other measures. The use of financial incentives or disincentives placed on operators with land uses causing non-point pollution have the potential to change individual management practices. Revenues can be directed towards abatement.

- **Conduct an inventory of farms for predominately agricultural watersheds**

An inventory of farms is needed to identify the waste sources that may be impairing environmental quality and to indicate the importance of the various sources of agricultural waste. Agriculture is usually considered a non-point source of contaminants as it is difficult to identify the point from which a contaminant escapes. Such identification is not impossible. A farm inventory would facilitate identification of specific pollution sources and allow source control procedures to be used for agricultural pollution. Watersheds include the Serpentine

River, Nicomekl River, Campbell River, the Boundary Bay watershed in Delta, and the Allouette/Pitt Polder area.

- **Streamline monitoring, remediation, and enforcement efforts**

Much of the current process is reactive as response to pollution from agricultural wastes is complaint driven. Agency coordination for more effective use of surveillance and enforcement resources is needed.

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Appendix A

Agricultural Waste Contacts

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